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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.
Imagery and GIS

The availability and resolution of remotely sensed imagery from earth-orbiting satellites and airborne, hydrographic, and terrestrial sensors have grown dramatically. While this data is potentially valuable to many different types of organizations, they must find a way to manage it while addressing problems related to data latency, accuracy, and format interoperability.

GIS provides a standards-based framework to manage data and mitigate these issues. With GIS, you can

- Integrate disparate data sources and manage large raster catalogs to provide enterprise accessibility.
- Promote interoperability.
- Perform dynamic server-side image processing from native data sources to minimize data latency.
World's Tallest Eucalyptus Tree Found with Lidar and GIS

_New Heights Reached with Technology_

By Aly Lawson, Esri Writer

A true giant among trees—the tallest known hardwood in the world—was discovered and mapped using a combination of lidar and GIS, the same technologies Forestry Tasmania uses on a daily basis for managing forests in Australia's southern island state of Tasmania. The swamp gum, a eucalyptus, was nicknamed Centurion and measured at 99.6 meters (326.8 feet) in height and 405 centimeters in diameter.

While tantalizingly short of the 100-meter mark, Centurion is the world's tallest eucalyptus tree and the tallest flowering plant. Only by few California coast redwood trees are taller. The tallest redwood is 115 meters. Redwoods are softwood trees, which grow taller than hardwoods, however botanists do not classify them as flowering plants.

Centurion was found about 80 kilometers southwest of Hobart, the capital of Tasmania, in a state forest near the Tahune AirWalk. "This discovery was basically a by-product of our sustainable forest management," said Luke Ellis, GIS manager of Forestry Tasmania, based in Hobart. The government-owned corporation manages more than 1.5 million hectares of state forest land, or 39 percent of Tasmania's forests. About half the forests Forestry Tasmania manages are available for sustainable timber production, and a network of formal and informal reserves on the state forests helps the company protect the environmental quality of its forests including flora, fauna, soil, water, and cultural heritage.
Centurion was initially detected during an aerial survey using laser equipment called lidar and analyzed using Esri's ArcGIS software. Lidar (light detection and ranging) is an optical remote-sensing technology that uses laser pulses to measure the properties of scattered light to find range or other information about a distant target. Like radar technology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

The use of lidar is attracting growing interest from foresters. The technology was first embraced by engineers, who recognized its ability to map terrain by accurately sensing ground surfaces, buildings, ore stockpiles, and similar features. It was used to enable more efficient quantity surveying, hydrologic mapping, and civil engineering design work based on accurate, high-resolution digital elevation models (DEMs) of the ground.

When lidar is flown over forests and other vegetation, only a portion of the laser pulses penetrate the canopy and reflect off the ground; the remainder is reflected off the trees and shrubs. Engineers have learned how to filter out the vegetation strikes and leave only ground strikes, from which a ground DEM is built. For engineers, each vegetation strike is just a missed opportunity for a ground strike. However, foresters quickly realized that by separating the signals into ground strikes and vegetation strikes, they can build two DEMs: one that maps the ground surface and one that maps the top of the tree canopy. By subtracting one from the other, foresters can get highly accurate maps of tree height—maps long used to monitor growth and assess site quality.
"Lidar promises to revolutionize forest mapping and inventory," said Martin Stone, resources manager for Forestry Tasmania. "With traditional aerial photography, accurate photogrammetry is impossible when the ground is obscured, so we were reliant on skilled but subjective manual interpretation. And the use of passive satellite imagery relies on statistical inference that has relatively low reliability at operational scales. Lidar, on the other hand, is an active sensor; it directly measures forest and land structure, accurately and repeatedly.

"We have found that we can use lidar data to model and map tree height, canopy density, and standing timber volumes, even in highly variable forests. And whereas older topographic mapping could only guess at the terrain under dense vegetation, the new lidar-based ground DEMs are accurately revealing streams and contours in great detail."

For Forestry Tasmania, this means more efficient planning of access roads and cable harvesting, easier delineation of harvest boundaries, improved silvicultural planning, and better environmental outcomes. Maintaining timber inventories should be more efficient, and the spatial variation of forests can be accurately mapped.
Lidar also means using GIS to a great extent. "At an average of two strikes per square meter of forested land, that's a lot of data to store and process," Ellis said about Forestry Tasmania's lidar data workload.
All of Forestry Tasmania’s lidar information is stored in the company’s Oracle Spatial relational database, which is used for effective data management and integration with other corporate systems. The Oracle data is efficiently replicated to a separate geodatabase, where Esri’s ArcGIS Desktop software is used to do the advanced geoprocessing and analysis of the lidar data.

Centurion as seen in Esri’s ArcScene.
"Ultimately, the result of our ArcGIS processing is a range of derived products that can be served to our foresters, planners, and engineers as GIS layers such as DEMs, timber volume surfaces, contours, and drainage lines. Most of this information can then be published in map formats, still the preferred medium for our field staff," Ellis noted.

"Our organization is very spatial, and everyone uses GIS in some form, especially in the field offices. The everyday user in forestry tends to work with GIS a lot to query data and browse and print maps. We use ArcGIS to do a range of important tasks-modeling and analysis, processing lidar, deriving spatial statistics, monitoring sustainability indicators for annual reporting, and just knowing how much of what we have is where."

All this, of course, means knowing the location of special trees like Centurion. The tree, which may be 400 years old, has obviously survived some close calls. Evidence of logging dating to the 1950s was discovered nearby. The tree also survived a massive wildfire in 1934 that passed just west of it and another fire in 1966 on its east side.

"No one was looking out for it in those days," Stone said. "We didn't know it was there. But thanks to lidar and GIS, it now has a name and it's on the map-literally." Centurion has now been formally designated as a giant tree and is protected in a preserve in accordance with Forestry Tasmania's policy.

(Reprinted from the February 2010 issue of ArcWatch e-magazine)
Monitoring the Albertine Rift in Africa

Custom Web GIS Functionality Facilitates Data Exchange

By Jared Stabach, Aggrey Rwetsiba, Dan Deneau, Greg Fiske, Wayne Walker, and Nadine Laporte

Highlights

- ArcGIS Server runs geoprocessing routines on the fly, such as extracting shapefiles and converting features to graphics.
- With ArcObjects, many custom tools and interfaces were built for the Web GIS.
- Data for five protected areas throughout Uganda is available within one access point.

Stretching from the northern end of Lake Albert to the southern end of Lake Tanganyika and spanning portions of Uganda, Rwanda, the Democratic Republic of Congo, Burundi, and Tanzania, the Albertine Rift is one of Africa’s most important—and most threatened—sites for the conservation of biodiversity. Formed over the course of millions of years, the Albertine Rift is the result of two tectonic plates that collided and are now slowly pulling apart. This geologic activity has created some of the continent's tallest mountains and a number of the world's deepest lakes and contributed to the diversity of habitats that include active glaciers, alpine grasslands, volcanoes, lowland and montane forests, and various grass and woodland savannas.

Since the early 1990s, however, this hot spot of biodiversity (home to more than 7,500 species of endemic plants and animals) has been plagued by a series of devastating conflicts, resulting in more than 3 million deaths and the displacement of approximately 2.7 million people. The region is one of the most populous in Africa, with up to 300 people per square kilometer in some locations. In addition to the pressures of population density, an influx of refugees and the lack of settlement policies have compounded the problem of forest degradation, fragmentation, and loss—particularly in protected areas.
Map of the Albertine Rift region.
The Need for Remote Sensing

Three years ago, the Woods Hole Research Center (WHRC) of Falmouth, Massachusetts, began working in the region to promote the development and use of remote sensing as a tool for conservation, with the principal goal to better facilitate the exchange of information between collaborative members of the conservation communities, such as the Wildlife Conservation Society (WCS) and the Uganda Wildlife Authority (UWA).

WHRC activities have included the integration of remote-sensing analysis into existing decision support systems (such as the Uganda Management Information System); the production of basemaps of land use/land cover, deforestation, and fire extent; and the development of monitoring tools that combine remote-sensing and biodiversity data.

The acquisition and exchange of this important conservation data, in turn, are intended to improve natural resource management, distribute spatial information to support conservation policy analysis, encourage a dialog across a broad user community, and provide technical training to support the long-term use of spatial data and analysis tools.

To better accomplish these goals, WHRC identified the need to provide data via a Web interface. While standard off-the-shelf Web GIS applications can easily be implemented, their generic interfaces lacked tools that were necessary to interact with both nontechnical and more technically inclined users (e.g., inability to access metadata information or to query raster datasets). Thus, WHRC teamed with the Institute for the Application of Geospatial Technology (IAGT) of Auburn, New York, which had experience building mapping applications, to develop a customized Web GIS application.

IAGT selected ArcGIS Server for the development of the Web GIS because the institute could take advantage of Esri’s ArcObjects. The ArcGIS Server platform allows users to do more than merely display and navigate the map. As users interact with the mapping application, ArcGIS Server runs geoprocessing routines on the fly, such as extracting shapefiles and converting features to graphics (and vice versa). Several custom tools were created to make the custom Web GIS application a more interactive and useful tool.

Building a Web Interface
Map showing density of Uganda Kob, a type of antelope, throughout Murchison Falls Conservation Area for the time period 1997–2004 and areas of high density throughout the savanna portions of the area. Data has been normalized to account for survey effort (distance walked within a 2 km grid cell). Image also highlights areas that have yet to be surveyed (no data).
Data for five protected areas throughout Uganda (Budongo/Bugoma Forest Reserve, Kibale National Park, Murchison Falls Conservation Area, Queen Elizabeth National Park, and Semuliki National Park) is currently available within one access point. The data displayed is a culmination of various remote-sensing-derived products (e.g., land cover, base imagery) and vector information that was collected by UWA rangers. These vector layers include general spatial information related to each of the protected areas (e.g., protected area boundaries, rivers, roads), information related to the threats throughout the park (e.g., encroachment, poaching), and wildlife sightings that have been collected during UWA ranger patrols (1985–present, depending on the protected area).

**About the Authors**

Aggrey Rwetsiba is the Uganda Wildlife Authority monitoring officer; Nadine Laporte is the PI of the Albertine project; and Jared Stabach, Greg Fiske, and Wayne Walker developed the GIS layers at the Woods Hole Research Center in Falmouth, Massachusetts. Dan Deneau is a software engineer for the Institute for the Application of Geospatial Technology at Cayuga Community College in Auburn, New York. IAGT specializes in geospatial application development and data processing.

**More Information**

For more information, visit [http://www.whrc.org/AFRICA/PAWAR/PAWAR-data.htm](http://www.whrc.org/AFRICA/PAWAR/PAWAR-data.htm). This work is funded by the NASA Application Program—Ecological Forecasting—Biodiversity, with additional funds from the National Science Foundation Human and Social Dynamics program.

(Reprinted from the Winter 2009/2010 issue of *ArcNews* magazine)
Cyclone Leaves Its Mark on the Map

Analyzing and Monitoring Myanmar's Damaged Rice Production Regions with GIS

Highlights

- ArcGIS software-based maps provide a detailed perspective of where remediation efforts are needed.
- Remote sensing and GIS are used to analyze global crop production capacity.
- Post-Cyclone Nargis GIS maps of Myanmar monitor the ongoing flood recovery.

With winds of 132 miles per hour, Cyclone Nargis, a category 3 tropical storm, struck the low-lying and heavily populated Myanmar coastline on May 2, 2008. The intense storm produced a 12-foot sea wave that flooded an approximate 2,000-square-mile area with a population of 24 million. Nargis left behind 90,000 fatalities and 56,000 missing persons in Myanmar, the country once known as Burma.

Adding to the tragedy of the human lives lost, the cyclone destroyed much of Myanmar's agricultural economy. The provinces of Ayeyardwady, Yangon, Bago, and Mon, which produce 58 percent of the country's rice crop—or roughly 6.2 million tons on a milled basis—were inundated with saltwater from the flood. In addition to the cropland damage, many villages were destroyed, along with much of their food stocks, livestock, and farming supplies.

Subsequent to Cyclone Nargis, the Foreign Agriculture Service (FAS) of the United States Department of Agriculture (USDA) began producing a series of commodity intelligence reports focusing on Myanmar's damaged agricultural areas. FAS' mission is to improve foreign market access to U.S. agricultural products, build new markets, improve the competitive position of U.S.
agriculture in the global marketplace, and provide food aid and technical assistance to foreign countries. FAS uses remote sensing and GIS software to analyze global crop production capacity, then issues commodity intelligence reports highlighting current international crop conditions. Published on the FAS Web site, these reports contain maps created with geospatial data and the technology found in ArcGIS software, which has been the USDA's standard GIS since 2001.

The maps that support FAS commodity intelligence reports include data from various sources. For example, satellite imagery obtained from the U.S. National Aeronautics and Space Administration's moderate-resolution imaging spectroradiometer satellite delineates the postcyclone flooding region. Combined with rice land-cover classification data from the Landsat satellite program and the tools in ArcGIS software, maps of the damaged rice production regions of Myanmar are easily created. These FAS-produced maps reveal the cyclone's effect on cropland and livestock, the severity of flooding, and the rate of cropland recovery. The United Nations (UN), nongovernmental organizations, and the international agriculture industry have also used these resources to evaluate the scope of the cyclone's impact.

Due to political issues within the Burmese military, relief efforts were slow, and little could be done in the days after the storm to aid in the recovery of Myanmar's flooded rice croplands, much less the salvation of its next harvest. Saltwater is a serious problem for rice cultivation, and Myanmar's inundated fields would need to be drained and flushed with sufficient fresh water before normal cultivation could be considered. Drainage became a problem even in areas where loss of life in the local farm population was light, because the rice fields are designed to store rainfall and freshwater irrigation. Not only did the cyclone destroy lives and property, it wiped out the country's agricultural economy indefinitely.
"Our GIS maps and flood classification data show that the areas originally inundated by the storm account for approximately 1.7 million hectares of rice—24 percent of the national rice area—or roughly 2.5 million tons of rice production on a milled basis," says FAS international crop assessment analyst Michael Shean. "The core region most severely damaged by the tidal wave and high winds, however, accounted for approximately 900,000 hectares of rice land, 13 percent of the national rice area, and roughly 1.35 million tons of milled rice production. In addition, field reports from inside the affected region indicate that within these rice production areas, large numbers of villages were destroyed, along with much of their food stocks, livestock, and farming supplies."

ArcGIS software-based maps depicting the cyclone damage in Myanmar provide the agriculture industry with a detailed perspective of where remediation efforts need to be conducted before the country can produce a normal rice harvest. In FAS' second commodity intelligence report, issued on June 10, 2008, GIS maps showed that approximately 80 percent of the original inundated rice production area was still affected by some degree of flooding. Fortunately, at that time, conditions in the core damage zone had improved considerably, with only 418,000 hectares, or 46 percent of the original area, still showing flood damage.

The June 10 report also stated that Myanmar's heavy rainfall season is approaching and that it was unknown whether the rain itself would provide sufficient aid in diluting the salt levels in inundated fields or in flushing saltwater from affected soils. In the meantime, the Myanmar government began seeking financial aid to acquire 6,000 tons of salt-tolerant rice seeds to sow approximately 100,000 hectares of rice in areas with the worst saline conditions. According to FAS map data, however, this still amounts to only 6 percent of the inundated region.

In the farmable areas, the morbid tasks of determining mortality and relocating human and livestock populations continue. A lack of accurate assessments on the ground about basic needs, such as food, shelter, drinking water, and farm supplies, have made it difficult for FAS or the UN to determine the actual capacity of recovered farming villages and their ability to cultivate a normal rice crop. Fortunately, livestock source data provided by the UN's Food and Agriculture Organization (FAO) is available. FAS used it to author a Cyclone Nargis Livestock Impact Analysis and GIS map. FAO data indicates that most rice farmers in Myanmar own two water buffalo or cattle to carry out their normal farm operations. Scientists estimate that nearly 200,000 cattle were killed in the storm. The FAS map is useful for prioritizing areas where donated cattle or even gas-powered farming equipment is most needed.
Post-Cyclone Nargis GIS maps of Myanmar generated by FAS have proven so valuable in monitoring the flood recovery in Myanmar that the agency has received custom map requests from many organizations. "Our maps and data layers are available on a case-by-case basis," says Shean. "We have recently been contacted by a couple of UN groups that are interested in our Myanmar flood analysis layers."

As conditions change and new data becomes available, FAS will continue to produce its own GIS maps, perform analysis, and issue commodity intelligence reports focused on Myanmar's rice production regions.

**More Information**

For more information on FAS commodity intelligence reports for Myanmar, visit www.fas.usda.gov.

(Reprinted from the Fall 2009 issue of *ArcNews* online magazine)
Better Crop Estimates in South Africa

*Integrating GIS with other business systems*

By Annalie Fourie, GIS Specialist, SiQ

Summary

Reliable crop information is vital to the functioning of grain markets. It is used to inform decisions on planting, marketing, and policy. Applying GIS to the process of preparing crop estimates has improved accuracy while lowering costs.

More accurate and reliable crop estimates help reduce uncertainty in the grain industry. The South African Department of Agriculture Crop Estimates Committee was tasked with producing crop estimates for South Africa on a monthly basis. To perform this task, the committee receives data from various input suppliers.

SiQ, a member of the National Crop Statistics Consortium (NCSC), uses statistical methods to provide inputs to the committee. Since 2002, crop information provided by producers has been used for statistical analysis. However, problems caused by producers who don't provide complete information, combined with a greater emphasis on improving statistical accuracy and efficiency, led to the development of an alternative system.

The Producer Independent Crop Estimate System (PICES) was developed in 2005. Implemented after a successful pilot study conducted in the Gauteng province, PICES uses crop field boundaries digitized from satellite imagery with a point frame sampling system to objectively estimate the area planted with grain crops.

The PICES process consists of the following steps:

1. Obtain satellite imagery.
2. Digitize crop field boundaries from satellite imagery.
3. Design the point frame and select random sample point.
4. Use aerial survey sample points to capture crop data.
5. Perform statistical analysis.
Satellite imagery for the project is made available by the South African government through the Department of Agriculture. SPOT Image Spot 5 satellite imagery with a 2.5-meter resolution is obtained from the department and is used as the base layer for digitizing.

An example of digitized crop field boundaries and the SPOT Image Spot 5 satellite imagery used for digitizing the boundaries.
Digitizing Crop Field Boundaries from the Satellite Imagery

This is done in ArcMap at a scale of 1:10,000. Comprehensive quality control measures are part of the digitizing process to ensure clean, accurate data of high quality. Detailed metadata is captured in ArcCatalog as soon as the dataset for a province has been finalized. This metadata is updated whenever changes are made to the dataset. All nine provinces of South Africa have been digitized—a total of approximately 12,965,000 hectares. The updating schedule and procedures ensure that the dataset remains current.

Designing the Point Frame and Selecting Random Sample Points

In the next step, sample points are randomly selected to represent potential cropped fields. These points will be surveyed in the field. A point grid of 45 meters by 45 meters is set up for the total provincial area. Grid points located outside field boundaries are removed from the sample population because these points are unlikely to locate crops.

Digitized fields are stratified based on the probability of finding a crop. The core strata used are high, medium, and low cultivation. High, medium, and low refer to the densities of fields within any given area as well as the presence of pivot irrigation and small-scale farming. Stratification is done to increase sampling efficiency. More sample points are used in strata where there is a higher likelihood of finding crops of interest. This will obtain the most useful data within budget constraints and keep the Coefficient of Variance (CV) as low as possible. [CV is the ratio of standard deviation to the mean; it is used when comparing datasets with different units or widely differing means.]

The grid points are selected per stratum and exported to a Microsoft SQL Server database. These points are sorted systematically from west to east and north to south. This is done to ensure an optimal geographic distribution of sample points. A random starting point is chosen and points selected at regular intervals according to the number of points needed in the specific stratum. The selected points are inserted into a new table in the database, and the process is repeated for each stratum. Finally, the SQL Server tables are added in ArcMap and converted to shapefiles containing the sample points for each stratum.
Aerial Surveying of Sample Points to Capture Crop Data

An aerial survey of the sample points is conducted. This aerial survey determines which crop is planted in the field represented by each sample point. These surveys are conducted by a field observation team that consists of a pilot and an observer in a very light aircraft. The observer is from the agricultural community and is very experienced at distinguishing between different crops and differentiating between dry land and irrigated cultivation. Typically, the number of sample points verified for each survey requires the use of more than one field observation team. This system of capturing field information for crop estimate purposes is believed to be unique in the world.
A Tablet PC connected to a GPS and running ArcPad is used to capture this data. ArcPad is customized with a user-friendly interface. The field observer notes which crop is planted at the sample point and whether it is dry land or irrigated cultivation. Additional information, such as growth problems or areas of double-cropping, is also captured. In addition to the data that is being captured, the observer also takes photos to provide more information on the conditions in the field during the specific survey. Each photo taken is automatically linked to a shapefile that indicates where it was taken.

The ArcPad interface used for data capturing in the field. The red squares indicate the randomly selected sample points displayed on a background of digitized crop field boundaries.
The field data is captured and stored in shapefile format. This data is uploaded to a central server on a daily basis and imported into a SQL Server database. Expansion statistics are used to calculate estimates of the area planted in each grain crop on a provincial basis.

The need to objectively estimate area planted under grain crops prompted the development of PICES. The system uses crop field boundaries digitized from satellite imagery together with a point frame sampling methodology and aerial field surveys to objectively estimate the area planted for each grain crop. PICES has proved to be extremely cost effective when compared with the previous system that used information gathered from producers. An area of approximately 12 million hectares can be covered in a two-month period using three field observation teams. The accuracy has also been improved by 40 percent per province. The use of GIS has greatly improved crop estimates in South Africa and resulted in more cost-effective, accurate, and objective grain area estimates.

Annalie Fourie is a GIS specialist for SiQ. She obtained her honours degree in GIS from the University of Pretoria, South Africa. She obtained her bachelor's degree in town and regional planning from the same university. Since 1999, she has been involved in diverse GIS projects.

(Reprinted from the Winter 2009 issue of ArcUser magazine)
Indian Government Selects Esri's Image Processing Platform

After an extensive competitive analysis, the Indian Space Research Organisation (ISRO) selected Esri's Image Management software platform to equip its five Regional Remote Sensing Service Centres (RRSSCs) with ArcGIS Server and its Image extension. The RRSSCs in Jodhpur, Dehradun, Kharagpur, Nagpur, and Bangalore, use Indian Remote Sensing (IRS) satellite and other imagery to create thematic maps and GIS databases that provide valuable societal applications to various government agencies throughout India.

With India's success in remote-sensing technology through the IRS constellation, several new imagery-based and GIS-centric projects of national relevance are gaining visibility and importance. ISRO is presently implementing major programs related to natural resources, disaster management, environmental oversight, and groundwater and watershed management.

The remote-sensing centers are establishing a distributed architecture of server-based solutions designed to be the foundation for publishing, hosting, and serving images and data. Over time, RRSSCs have collected large volumes of map data and integrated them with developmental attribute data. The centers plan to combine and assimilate all the data with new-generation IRS high-resolution images and serve the data and application sets across the government sector.

The RRSSCs needed a GIS solution that met their needs and was scalable to meet growing demands for services from a large number of users for a variety of advanced applications. They selected Esri's proven technology and superior solutions after several rounds of technical presentations, demonstrations, and discussions. RRSSC and NIIT GIS Limited (Esri India), Esri's distributor in India, have concluded a comprehensive training session, and RRSSC users have started developing the solution.
Dr. Yvn Krishnamurthy, director of the RRSSCs, says, "ISRO users have been using Esri products for a variety of applications, and many national programs have been based on GIS solutions. IRS imagery has been the source of thematic mapping inputs and provides end-to-end solutions under the umbrella of the National Natural Resources Management System. ArcGIS Server with the Image extension is a robust and integrated product and has capabilities that can meet our application needs of serving images and thematic maps to a variety of users."

Dr. Mukund Rao, president and chief operating officer at Esri India, notes, "ISRO has been pioneering the use of IRS imagery and advancing GIS solutions for a long time. We are proud to be associated with them on this prestigious, first-of-its-kind national project to serve image- and map-based solutions in a GIS portal architecture."

ArcGIS Server helps users connect people with the information they need via Web mapping applications and GIS services. It is built on a modern, service-oriented architecture. The ArcGIS Server Image extension makes it possible to take raw or preprocessed imagery and immediately deliver it as a Web service. It enables organizations to exploit the rich information content available in imagery and quickly access large volumes of imagery. This is far superior to traditional options that required significant efforts by users to locate and make file-based imagery available.

Says Lawrie Jordan, Esri’s director of imagery enterprise solutions, "We provide powerful new tools that enable things to happen in near real time—like delivering and displaying imagery, roaming around the imagery, zooming in to the imagery, and doing on-the-fly mosaicking and orthorectification of the imagery."

Esri India envisions that this new software deployment and implementation will serve as a key reference within all Indian government agencies, especially those that disseminate and/or consume imagery and imagery-related data.

(Reprinted from the Summer 2009 issue of ArcNews magazine)
Manitoba Responds to Red River Flood with Common Operating Picture

*ArcGIS Online Services Combine Basemaps, Imagery, Real-Time Data*

Highlights

- The COP, based on ArcGIS online services, helped achieve an accurate visual of the unfolding natural disaster.
- The application was intuitive, aligning all organizational goals into a single platform.
- The COP was used to quickly identify residents to prioritize for evacuation.

With crests rising to more than 20 feet, the spring 2009 Red River flood surpassed the floods of 1950 and 1979 to become Manitoba, Canada’s second highest since record keeping began in the 1800s. The situation was exacerbated by seasonal snowmelt, powerful ice jams, flash flooding across the province, and heavy rainfall. In response, Manitoba Health’s Office of Disaster Management (ODM) funded the development of a common operating picture (COP)—an effective visualization tool that enabled the province to achieve real-time situational awareness, act quickly, and communicate its response plan to key stakeholders.

During the flood, ODM was tasked with ensuring the continuity of health services for community residents and that emergency operations remained uninterrupted. To meet these challenges, ODM needed a tool that would allow it to analyze the current situation, predict future outcomes, and make critical decisions—such as deciding which roads to open and close, which residences and buildings to prioritize for evacuation, and which routes were most effective for emergency vehicles to travel. It also needed to communicate these decisions quickly and effectively to senior decision makers to enable them to take action and mitigate risk to residents. With few resources available to implement a complex system, the situational awareness tool would have to be simple, intuitive, and able to guide users through the four stages of emergency management—mitigation, preparedness, response, and recovery.
The Red River shown with several tools, including a service area locator, stream gauge updater, and links to live weather stations.
ODM sought a partner to help develop the tool and selected the expertise of Esri Canada Limited, Esri’s distributor in Canada. Together, they built the common operating picture with ArcGIS online services to combine basemaps, imagery, and real-time data into a map window, so that ODM could achieve an accurate visual of this unfolding natural disaster. The data sources included satellite imagery, data from CanVec (a cartographic product by Natural Resources Canada), and geospatial data from the Manitoba Land Initiative. Environment Canada’s Web site was monitored on a regular basis for the latest weather conditions and forecasts to continuously gauge stream flows. Real-time weather data and topographic information were also combined to predict future outcomes and trigger evacuation events.

The team then developed and displayed a multitude of ArcGIS online services layers of the COP to represent personal care homes, emergency medical services (EMS) facilities, helicopter landing zones, hospitals, ring dikes, ice jams, broken bridges, and ambulances. Using intuitive symbology, these layers were easily interpreted and allowed users to zero in on problem areas for effective analysis. The team also extracted road segment data from the Medical Transportation Coordination Centre and incorporated it into the COP to communicate road closures. Intuitive symbology and real-time data empowered ODM to provide effective support to operations on the ground and quickly solve challenges, such as ice jams and road closures.

"Our group had limited knowledge of GIS, and there was no time to secure additional resources," says Gerry Delorme, director, ODM. "However, the common operating picture was so intuitive and easy to use that it allowed us to align all our goals into a single platform and be fully operational quicker than I ever imagined possible."

In around-the-clock operations, ODM referred to the COP to conduct thorough data analysis, make 20 to 30 critical decisions each day, and address the four stages of emergency management. During the mitigation phase, the tool provided an answer to the question, Where has there been a flood like this before? Using the Live Maps layer, ODM was able to sift through data from similar floods in 1950, 1979, and 1997 to uncover recurring patterns.

During the preparedness phase, there was concern that the Red River Floodway would not divert enough water and that ice jams would block the floodway. If this had happened, ODM would have needed to quickly identify residents to prioritize for evacuation. To take a proactive approach, it leveraged the COP’s ArcGIS online services to generate demographic reports that revealed information such as the percentage of senior citizens in a specific area.
The COP addressed the response phase of emergency management by enabling ODM to monitor environmental factors affecting the flood, such as heavy rainfall. Links to weather stations throughout the province provided a constant update on the latest weather conditions and forecasts. The COP also enabled ODM to investigate stream gauges in individual communities to determine how specific areas would be impacted by the flood during peak times and coordinate response activities. Finally, during the recovery phase, ODM was able to look back at a historical record of flood activity and analyze RadarSAT data from earth observation satellites to view polygons that marked the flooded areas.

In addition to serving as a powerful decision-making and problem-solving tool, the COP was used during ministerial briefs with the deputy minister to explain and justify emergency management planning. The ability to communicate effectively meant that operational response times were greatly reduced, and ODM could focus on taking action to ensure the safety of Manitoba residents. This fusion of critical information allowed collaborative planning during one of the most severe natural disasters in Manitoba's history.

"The COP was the first thing we looked at every morning," explains Delorme. "The ability to assess what had happened since we last looked at the application and what was currently happening helped us form quick and confident predictions about where things were headed."
Looking forward, ODM will continue to integrate more data sources into the COP, including a recently purchased public alert communication system. ODM also plans to use the tool to monitor ambulances and hospital bed counts in cases of emergency.

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Colombian Coffee Growers Use GIS to Brew Better Crops

Highlights

- Crop forecasting is carried out using ArcGIS analytic tools.
- Field service teams can upload data using the ArcGIS Mobile application.
- ArcGIS Server Image extension manages and publishes large volumes of geospatial imagery.

The coffee harvest is a historic component of the Colombian economy that can be traced back more than 300 years to the arrival of Jesuit priests from Venezuela, who began its cultivation. Today, the harvest represents about 10 percent of Colombia’s total exports, and the industry employs more than 500,000 people in its coffee production operations. Most farms are small producers, with less than five hectares of coffee trees under cultivation.

In 1927, the Federación Nacional de Cafeteros de Colombia (FNC) was formed to represent the interests of the small coffee growers in the country. However, because of the large number of coffee growers, FNC faced a problem in centralizing the data collected from these farms. This impacted the federation’s ability to negotiate better coffee prices based on coffee yield predictions across the entire country.

To improve its forecasting capabilities, FNC conducted an extensive survey of coffee production in Colombia nearly 20 years ago. The resultant Encuesta Nacional Cafetera (ENC) is the standard on which the regularly updated Sistema de Información Cafetera (SICA) is still referenced today. SICA is a system that provides the fundamental data infrastructure and strategic information used in the design, formulation, and tracking of Colombian coffee farming. The current version of SICA has been based on ArcGIS Server software since 2008 and is used for online information analysis, planning, sustainability policies, decision making, competitive analyses, environmental monitoring, crop forecasting, farm registration, and quality assurance. FNC had been using ArcGIS Desktop software for many years and naturally selected ArcGIS Server to upgrade SICA.
The model ENC survey included a collection of aerial photographs that were orthorectified using Esri's GIS software for inclusion in the original SICA geographic database. Today, the ArcGIS Server Image extension is used to manage and publish the large volumes of geospatial imagery that it collects from remote-sensing sources, such as orthophoto mosaics, satellite imagery, and aerial photography, for inclusion in SICA. The technical staff at FNC uses ENVI image processing software for multitemporal analysis and research on the collected imagery.

An individual parcel is selected within FNC's coffee crop sample area. Displayed data includes its latitude-longitude location and various identification codes.
Crop forecasting is carried out using ArcGIS analytic tools on SICA data, which includes georeferenced samples collected by FNC field service teams within specified cultivated areas. To conduct the biannual sampling process, more than 1,000 field technicians harvest both ripe and unripe beans from coffee trees in each specified area. The beans are counted and weighed, then statistical processes are applied to extrapolate crop estimates for the succeeding six-month period. After completing their samplings, the FNC field service teams upload the crop yield data into the SICA geodatabase through either an Internet-based server application or a custom-built ArcGIS Mobile application. Because the FNC GIS is Web based, near real-time updating of the SICA database can now be performed.

The collected data is also analyzed by Cenicafé, FNC's research center, and the federation provides reports to its members regarding its critical findings. Current research topics include erosion management; soil remediation; and the multiple ways in which the coffee harvest is affected by changing environmental factors, such as variations in rainfall and temperatures.

FNC also monitors the socioeconomic issues that affect the coffee farmer. SICA maintains information regarding the educational opportunities for FNC members, the condition of the infrastructure in their towns and villages, and the health care facilities available to them.

GIS has proved to be an invaluable resource for the Federación Nacional de Cafeteros de Colombia and its constituent farmers. The technology not only provides a wide range of services related to coffee crop forecasting and associated research but also allows the federation to track the quality of life of its members. This provides a compelling example of the power of GIS and how it can help improve the socioeconomic conditions of people throughout the world.

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Mapping Riparian Vegetation with Lidar Data

Predicting plant community distribution using height above river and flood height

By Thomas E. Dilts, Jian Yang, and Peter J. Weisberg, University of Nevada, Reno

Combining GIS and lidar data enabled predictive mapping for riparian areas for a portion of the Sierra Nevada mountain range.

Riparian areas pose many problems for vegetation modeling because of their narrow width, dendritic pattern, and the sensitivity of plant species to subtle changes in topography that cannot be easily recorded by coarse-scale digital elevation models (DEMs). Vegetation mapping and monitoring in riparian areas have relied heavily on field-based surveys that record the distribution of plant communities along transects perpendicular to the river.

Typically, these studies also collect ancillary variables, such as stage elevation or height above the river (HAR), soil texture, and soil moisture, that are used to predict the distribution of vegetation types. However, these methods are extremely time consuming and do not allow for the development of predictive maps because the data collected cannot easily be extrapolated to a larger region. GIS and lidar data provide an opportunity to derive variables, such as HAR, for large areas, making wall-to-wall predictive mapping a possibility.

Deriving HAR from Lidar Data

Developing cross section profiles akin to traditional survey methods posed a number of problems. It is time consuming to digitize the thousands of cross sections that would be required to cover the entire 200-mile stretch of the Walker River, which runs from the Sierra Nevada range in eastern California to Walker Lake in western Nevada.

However, automated approaches for generating transects also entail problems. If the transects are generated perpendicular to the river, the density of transects is less on the outside of a river bend than on the inside of that river bend. If transects are generated perpendicular to one another, they do not always cross the river at right angles. One-dimensional methods also suffer from problems because points located on different transects may be close to one another geographically yet have very different values because the transects they are on intersect the river at different elevations. When producing a predictive map from such data, the result is many abrupt changes over small areas that make the map difficult to interpret.
The figure on the left shows cross sections that have been generated perpendicular to the river crossing the river channel every 10 meters. The figure on the right shows horizontal cross sections that are generated every 10 meters. Both figures illustrate the problems with automated methods of generating cross sections. On the left, large gaps are left in areas where coverage of cross sections is poor. Where cross sections come close to one another, values can differ greatly because they refer to different parts of the river. On the right, the cross sections can intersect the river in more than one location.

The authors of this study considered two-dimensional methods as an alternative to the traditional one-dimensional method of constructing stage elevation from lidar data. Hydrologic functions in the ArcGIS Spatial Analyst extension were used to fill the DEM (i.e., to remove local "sinks" caused by errors in DEM construction) and calculate flow direction and flow accumulation for each grid cell.
The resulting flow accumulation grid was reclassified and subsequently edited so that the resulting stream network only included cells where the Walker River was located. A custom model was developed using ArcGIS ModelBuilder to calculate HAR. The model uses the Spatial Analyst extension’s kernel density function to calculate a distance-weighted average of river elevations, where cells in the river that were nearer to the upland grid cells receive a greater weight than cells located farther away. The weighted average river elevation was then subtracted from the elevation of individual grid cells to derive HAR for each location.

ModelBuilder, part of ArcGIS Desktop, was also used to derive additional variables from the HAR grid. Spatial Analyst cost-distance functions were used to identify grid cells below a user-specified HAR threshold that were physically connected to the river channel. This algorithm was extended iteratively using ModelBuilder to calculate inundation areas at one-centimeter vertical intervals up to five meters above the river. The inundation values from each iteration were summed and subtracted from 500 to get a flood height grid. The flood height grid describes the flow stage required to inundate a given grid cell, assuming a simple bathtub model. [A bathtub model is a steady-state water quality model for simplifying the assessment and prediction of conditions in reservoirs and lakes as related to eutrophication.] Low-lying cells separated from the river by higher ground required a flood height greater than the HAR value.

Results

The HAR method described here produced maps that were smoother, easier to interpret, and required less time to produce than ones created using comparable one-dimensional methods. All calculations were performed using ArcGIS and the Spatial Analyst extension and did not require fieldwork. The kernel size can be adjusted to vary the extent and smoothness of the height-above-river map. Larger kernel sizes incorporate longer stretches of the river into the calculation allowing greater mapping extent and a smoother surface. A smaller kernel size results in a smaller extent but more detailed and more precise estimates.
The figure on the left is a 0.3048-meter-resolution aerial photograph of the Walker River in Nevada. The image on the right is the height-above-river map using a 300-meter kernel size and classified into 50-centimeter vertical intervals. In the upper left-hand corner is an eutrophic oxbow lake that is low lying yet disconnected from the river channel. Near the bottom of the map is a shallow river channel that periodically fills with water, cutting off the point bar. An irrigation ditch is visible on the right-hand side of the image.

Estimates appear to be most accurate along low-gradient stretches of the river with few tributaries. These are precisely the same areas where a typical low-resolution DEM would have the most difficulty detecting subtle changes in elevation. Stretches of river with a non-linear gradient and tributaries with strongly differing gradients are likely to produce less accurate results.
HAR and flood height were incorporated into statistical models to predict the distribution of vegetation communities within the Walker River Basin. When predicting the 10 major vegetation communities in the basin, HAR and flood height were the first and second most important predictor variables. Wetland vegetation and communities dependent on frequent flooding exhibited the lowest HAR values, while communities that tended to be located farther from the river but were still dependent on groundwater exhibited higher HAR values. Upland communities able to tolerate low water tables had the highest HAR values.

**Future Directions**

As restoration efforts move forward for the Walker River Basin, HAR and flood height maps will be incorporated into a decision support system that helps land managers identify low-lying areas that can be reconnected to the river channel. Using HAR and flood height maps will help minimize costs by targeting areas where restoration is most likely to be successful. Currently the Great Basin Landscape Ecology Lab is using Toolbox for Lidar Data Filtering and Forest Studies (Tiffs) software developed by Qi Chen to delineate individual tree crowns derived from lidar. The individual tree maps will be used to map bird habitat and improve on existing vegetation maps for the Walker River Basin. Finally, the authors plan to make the HAR and flood height models available to the GIS community as part of the Riparian Topography Toolbox, which will be available on the ArcScripts Web site (www.esri.com/arcscripts).

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**References**


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Dr. Jian Yang is a postdoctoral researcher at Great Basin Landscape Ecology Lab at the University of Nevada, Reno. He received his bachelor's degree in geography in 1997 and his master's degree in ecology in 2000. In 2005, he received his doctorate in forestry from the University of Missouri. His Ph.D. work focused on forest landscape fire and succession modeling. He was the developer of the LANDIS fire module, which has been applied in many ecosystems across the United States (e.g., California, Missouri, and Wisconsin).

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GIS Gives Port a Common Operating Picture

*New users and data reuse optimize port activities*

By Karen Richardson, Esri Writer

A server-based enterprise GIS implementation created by the San Diego Port Authority has empowered staff across the organization by centralizing the maintenance of and access to GIS data and CAD drawings.

The Port of San Diego maintains a diverse facility spread across 6,000 acres. With the exception of the San Diego Convention Center, the San Diego Port Authority is responsible for the port: park and concessionaires, the walkway, large public art installations, two marine terminals, and a cruise ship terminal surrounding San Diego Bay. Operating these assets generated revenues of $133.7 million in 2007. The port, which uses information technology (IT) enterprise systems, such as SAP and a document system to manage business information, realized that applying the same concept to space management would be advantageous. The system the port envisioned would be accessed by every department and used by anyone from summer interns to the CEO.
With GIS, the Port of San Diego can efficiently manage assets located on 6,000 acres surrounding San Diego Bay in California.

The port had been using GIS since the 1990s in the engineering and real estate departments. Although both departments were essentially creating and using the same data, this data was not shared and efforts were duplicated. However, there was no easy way to share data.

“Our vision of creating a common operating picture with a geographic perspective gives everyone the information they require along with the basic GIS functionality necessary to do their jobs in the best way they can,” explained Malcolm Meikle, geographic information systems coordinator for the San Diego Unified Port District.

Three years ago the port's information technology department added ArcGIS Server, a complete and integrated server-based GIS, to its ArcGIS Desktop software. This change made facilities data accessible to the departments that needed it. The goal was to streamline workflows by identifying tasks, questions, and requests that were best answered using a geographic approach. This approach paid off. "Using GIS, the time it takes to access critical information went from seven to eight hours to mere minutes because the data is now located in one location and it is up-to-date," said Meikle. "Just this change has sped up our workflow and is driving faster, more informed decision making."
The port worked with various departments to customize interfaces using ArcGIS Desktop and generic Web browsers to give access to port data that now resides in a single location: a geodatabase. The geodatabase is the common data storage and management framework for ArcGIS Server. Source data is also managed in the geodatabase, which minimizes redundant copies and eliminates the possibility of varying versions of data.

Adopting new technology to improve business processes can be a daunting task. The port found it needed to keep daily tasks as unchanged as possible while incorporating tools for bringing real benefits to the users. CAD has continued as the technology used in the data production environment for creating drawing files for structures around the port. Designers use the ArcGIS for AutoCAD extension, a free tool from Esri, to bring GIS data into the CAD environment. Using this extension, engineers can continue working with familiar software while gaining access to GIS data. It can be GIS data created in-house or GIS data from ArcGIS Online, an Esri-hosted repository of GIS maps, layers, and tools.

ArcGIS for AutoCAD has proven to be a valuable tool since it allows operators to see the GIS basemap in their native CAD environment and find answers to questions because all the information is accessible through the basemap. "AutoCAD users are drawn to this tool because it gives them a window into GIS information while still allowing them to work in their familiar AutoCAD environment," said Ari Isaak, a GIS analyst for the San Diego District Port.

Creating an enterprise GIS has driven the implementation of data and file structure standards in the engineering department so CAD data can be seamlessly displayed and analyzed through the wide variety of ArcGIS Server clients. Web-based clients, accessible to all port employees, provide new tools for understanding the infrastructure the port manages and maintains. Users in engineering management and general services and asset managers in the real estate department also use these tools.

Moving data from CAD to GIS, CAD operators must follow naming conventions for drawings, layers, objects, and attribute blocks. The port adopted the United States National CAD Standard—which is used by organizations throughout the United States for exchanging building design and construction data—as a guideline for its own CAD data standards. The Department of Homeland Security Geospatial Data Model is used as a data model guide.
Using the ArcGIS for AutoCAD extension, engineers can bring GIS data into a familiar CAD environment and access GIS data whether it is created in-house or is accessed from ArcGIS Online.

All scanned paper plat and record drawings are accessed by an intermediate table that contains relevant information about the documents that are stored in the geodatabase. Standardizing layer naming conventions for new drawings, as well as the creation of a master CAD drawing, means that engineering staff update those files instead of storing these drawings on local drives. This ensures that every department can understand and use GIS data. This has made attribution much easier, and CAD operators no longer need to guess how to describe features in the drawings.
Another advantage of this system is the ability to view and use imagery in the CAD stations using the ArcGIS for AutoCAD tool. In the past, when engineers added TIFF images to AutoCAD—one at a time—the draw time was lengthy. If a drawing spanned more than one image, each image had to be loaded separately. This process was time consuming and frustrating for operators. "CAD designers love ArcGIS for AutoCAD if for no other reason than they finally have access to very high-resolution aerial [photos] quickly," said Isaak.

The port has two sources for imagery: .3-meter resolution aerial photographs from ArcGIS Online and 4-inch pixel resolution aerial photos flown in April 2009 by the port. The 4-inch resolution photos are used for quality control and as a source for creating new data. To use the aerials for these purposes, engineers must follow strict standards and use the same coordinate system employed by the GIS operators.

This simple change has been advantageous. Now, drawings can be viewed in the correct geographic space even if an image is not used as a backdrop. Drawings can also be located by performing a spatial search rather than by the name of a drawing. Now drawings can be used for more than one project. Previously, drawings had to be copied and pasted into work projects. These changes have cut down on the errors inherent in copying data and the amount of file space needed to store the drawings. Because the source data is managed in the GIS database, it can be used more than once. Now, everyone in the port is using the most accurate data.

"By using geographic data and systems, the port is able to use geography as the common factor to bring together data that otherwise is difficult to integrate," said Meikle. In 2007, when ArcGIS was adopted, the GIS group moved from the real estate to the information technology (IT) department. This allowed IT to manage and disseminate GIS data throughout the port. Access to the GIS data and system has empowered the port's employees to integrate their own independently developed workflows for managing spatial data and accomplishing their work using the information they need.

Departments that traditionally hadn't thought about using the port's facility information, such as the harbor police, are now users. Today, the harbor police employs two applications for tracking vehicles around port property—one desktop application built with ArcGIS Explorer and an in-car application that displayed map data in Web browsers that was created with OpenLayers, an open source JavaScript library.
Staff throughout the port can access the GIS through the PortGIS Resource Center. This central gateway to GIS information is accessed by clicking an icon on the port’s internal Web home page. Here, staff can choose one of three Web applications—PortGIS Explorer, PortGIS Utilities, or PortGIS Projects—designed for various tasks and departments.

“Our vision of creating a common operating picture with a geographic perspective gives everyone the information they require along with the basic GIS functionality necessary to do their jobs in the best way they can.”

—Malcolm Meikle, GIS Coordinator for the San Diego Port District
The most used GIS Web application is PortGIS Explorer. Staff can access high-resolution aerial photos and the port's TideLands Mapbook, which represents the port's overall geographic interests at the Port of San Diego. A user can navigate around the map to see exactly the information they need, turn on and off layers, and create maps to include in reports and e-mails. Data can be queried and measurements between two or more points obtained.
The PortGIS Utilities application focuses on current conditions. End users can view utility line work and access PDFs of official engineering drawings by location. This application furnishes all the functionality of PortGIS Explorer as well as georeferenced maps from important documents. PortGIS Utilities brings together the port’s development effort affecting all the managed land and creates a common operating picture for departments as they move forward in their planning efforts. The PortGIS Projects application deals with future developments, the regulatory process, and obligations to which the port is committed.

The central clearinghouse for the port’s utilities data, PortGIS Utilities, enables engineers to find electrical, fire, natural gas, fuel, sanitary sewer, storm drain, telephone, water, chemical, fiber optics, and communications lines more easily and share the information with the rest of the port.
PortGIS Utilities is the central clearinghouse for the port's utilities data, including electrical, fire, natural gas, fuel, sanitary sewer, storm drain, telephone, water, chemical, fiber optics, and communication lines. The data is converted to Esri feature classes using a batch file, which runs nightly. Instead of the engineers working with a traditional file system to structure the data, the data is spatially indexed so it can be more easily located. This also allows engineers to share data with the rest of the port. Simply having the data created using standards that are managed and shared from one location makes it much easier for staff to find answers.

The entire system was built using the Microsoft .NET framework, a file geodatabase, and Windows Server 2008 on a 64-bit machine. Clients were created using the .NET Web Application Development Framework (ADF) that comes with ArcGIS Server, which was customized using Visual Studio and incorporated many ideas from the .NET ADF Code gallery at the Esri Web site. The IT department also created a streamlined method that assists users by installing software remotely. If staff members have questions, they can send e-mails to the IT department or check out a %scratchworkspace% (posdgis.wordpress.com/), a blog maintained by the port GIS professionals.

Today port staff can not only ask questions like How much square footage is available? but also reach further into the data by gaining access to official record drawings and viewing the relationship between a developer's plans and the geographic interests of the port. GIS is used in every department. It helps the harbor police track police cars. The general services department uses it for engineering data accumulation and maintenance. The finance department uses GIS to track money coming into the port by tracking corporate leases, maintaining parking meters, and other activities. Today the more than 600 employees at the port can use GIS data and Web-based applications.

For more information, visit the CAD Integration Resource Center (resources.esri.com/caddata). For more information on ArcGIS for AutoCAD and to download the free extension, visit www.esri.com/arcgisforautocad.

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